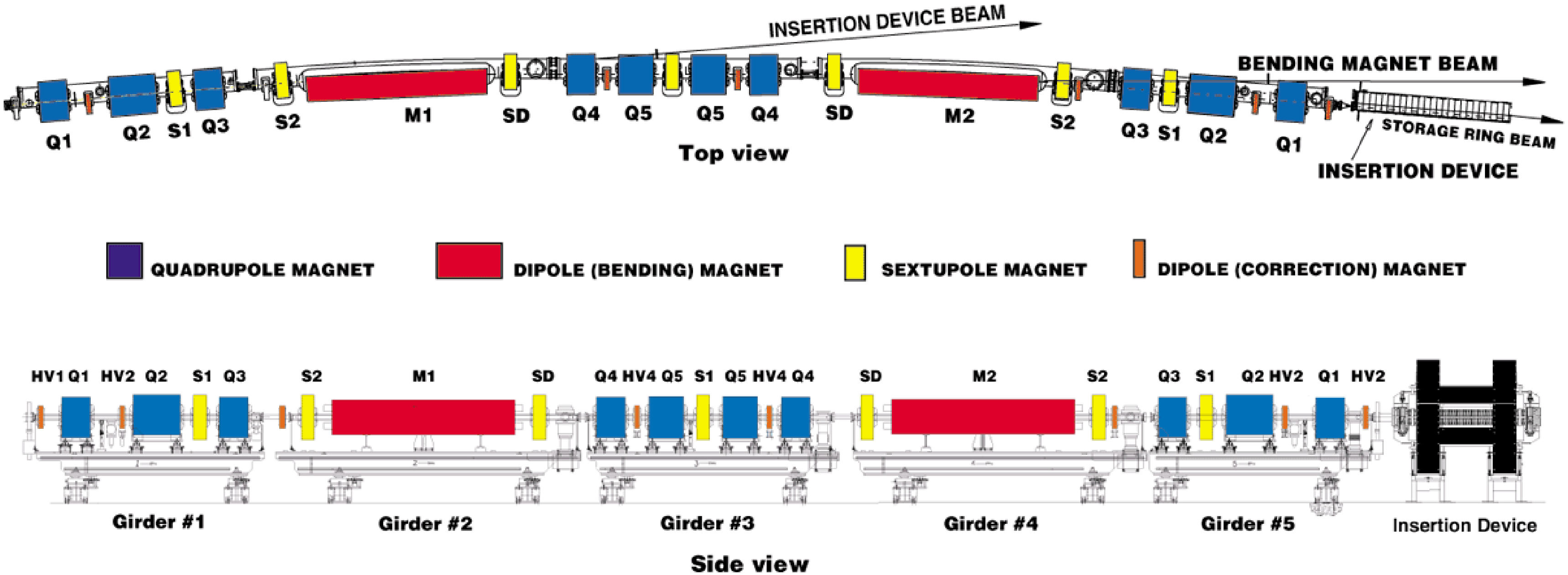
Orbit Feedback Using X-ray Beam Position Monitoring at the Advanced Photon Source

Glenn Decker

- **APS beam stability specification**
- **System overview**
- **Accomplishments to date**
- **Improvement plans**

One Sector of the Advanced Photon Source Storage Ring



27.6 meters

(APS has forty sectors - 1104 meters total circumference)

APS Beam Stability Specification

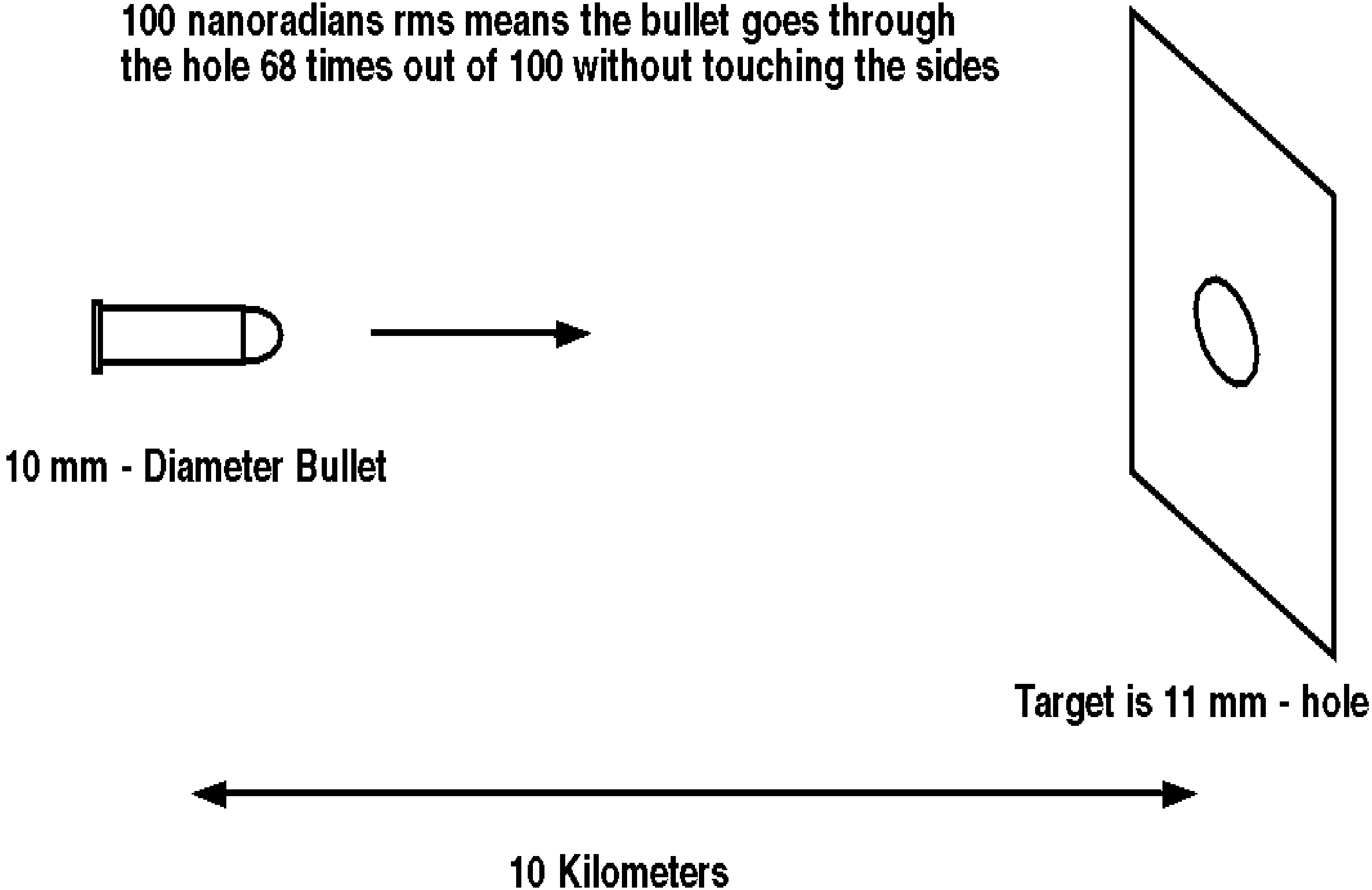
1) Original engineering specification 5% of CDR beam size values

- 4.5 microns rms vertical (@ ID source points)
- 17 microns horizontal

2) With present low-emittance lattice, (1% coupling) this amounts to

- 590 nm / 120 nanoradians rms vertical <------
- 12.6 microns / 900 nanoradians rms horizontal

100 nanoradians rms means the bullet goes through the hole 68 times out of 100 without touching the sides



APS Orbit Correction System Components

- 360 broadband (monopulse) RF BPMs
- 48 narrowband RF BPMs (mounted on ID vacuum chambers)
- 48 insertion device X-ray BPMs
- 38 bending magnet X-ray BPMs
- 317 combined-function horizontal / vertical corrector magnets

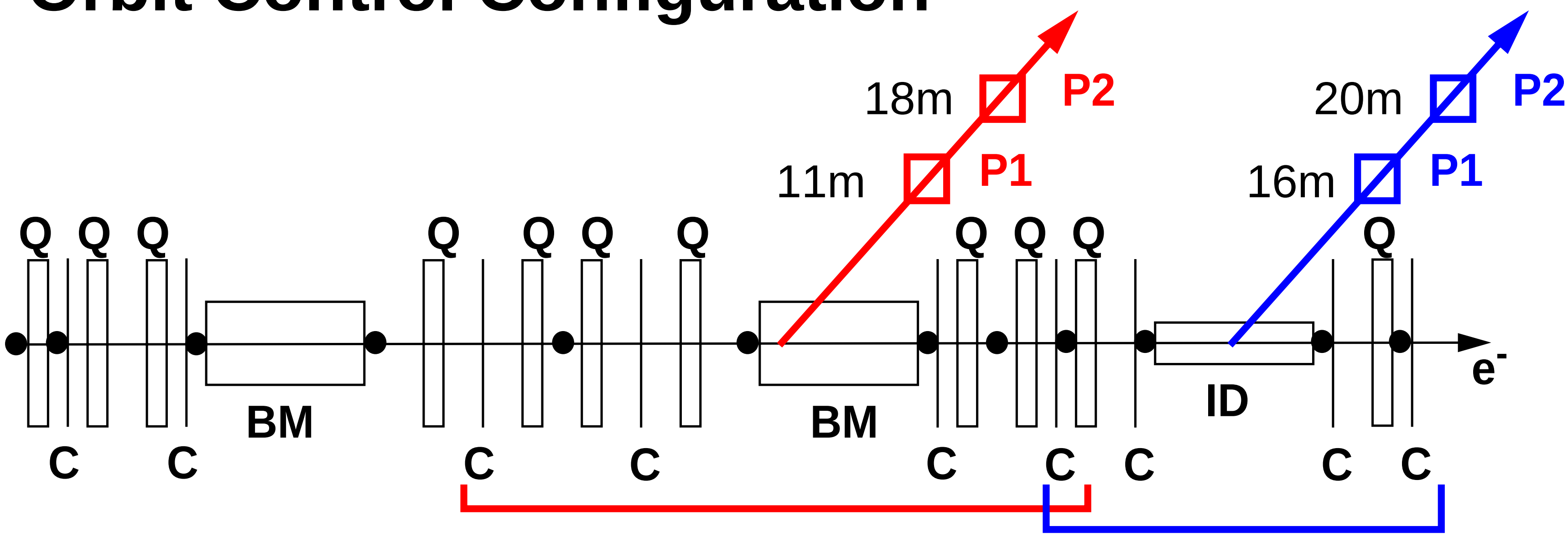
APS Orbit Correction System Components (cont'd)

- 21 VME crates, each with 2 DSP boards [Pentek 4283 (TI C30 DSP), 4284 (TI C40 DSP)]for real-time feedback. [4285 (multi-C40 board) used in "master" crate.]
- One additional 4284 DSP board used in feedback crates for X-ray- and narrowband RF- BPM data acquisition and filtering.
- Singular Value Decomposition (SVD) algorithm used in DC and AC systems.
- Workstation-based (DC) algorithm has 0.1 Hz closed loop BW
- Real-time (AC) algorithm operates at 1.5 kHz allowing closed loop bandwidth from 0.1 to 60 Hz

  - Access to 38 "fast" correctors

  - Access to all RF and X-BPM data (not all used in algorithm)

Orbit Control Configuration



Legend:

C: Corrector Magnet

● RF Beam Position Monitor

P1,P2 : X-ray Beam Position Monitors

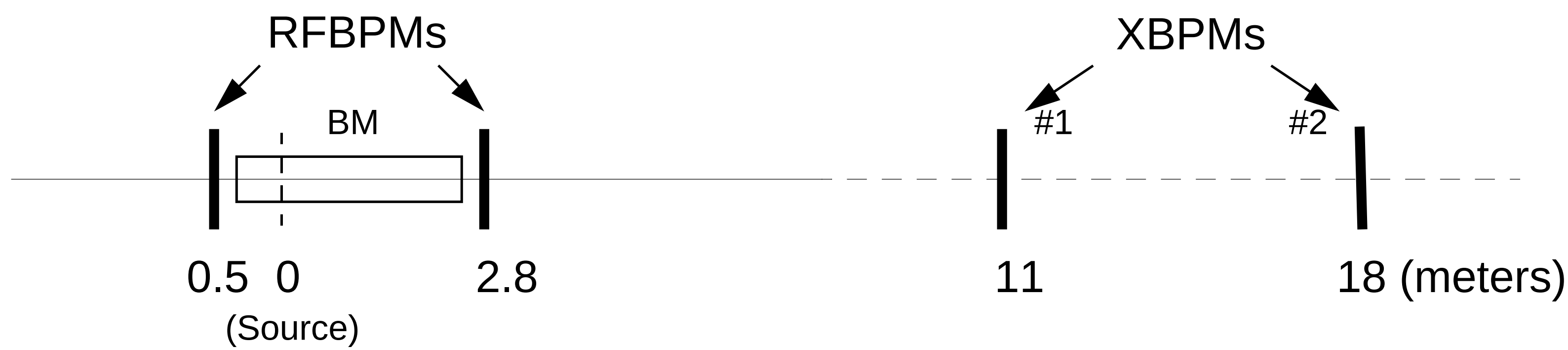
Q: Quadrupole

BM: Bending Magnet

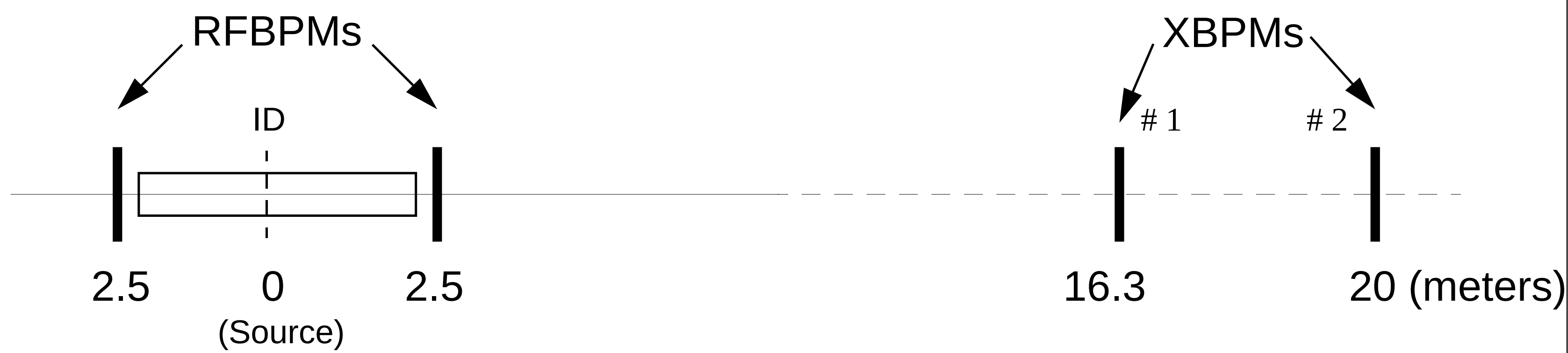
ID: Insertion Device

Config.	BPMs	Correctors
Global	11 RF (all)	2
Local - 1	P1 or P2	4
Local - 2	P1 and P2	4

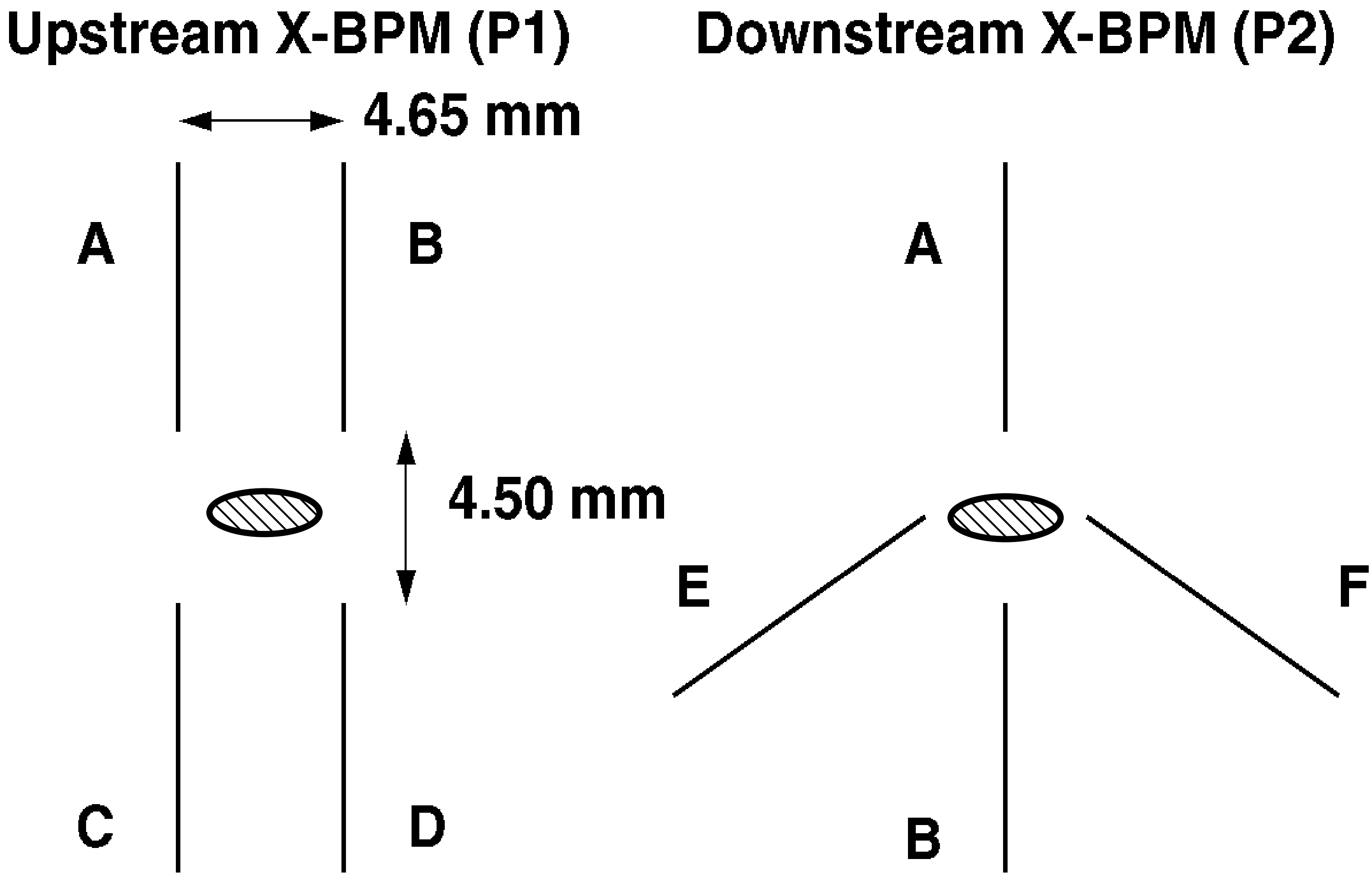
Bending Magnet and BPM Layout

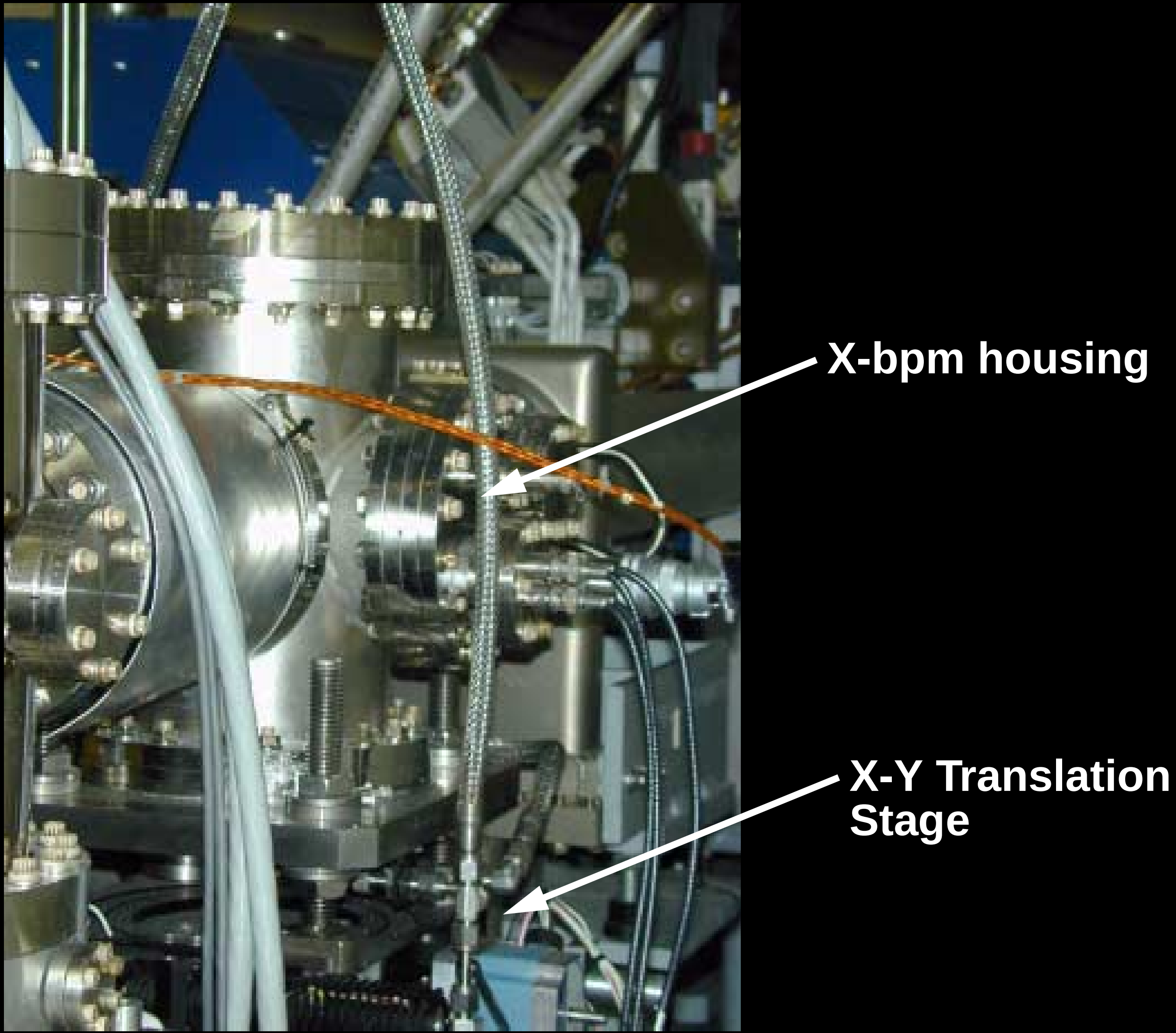


Insertion Device and BPM Layout



APS X-ray BPM Photoemission Blade Sensor Geometry



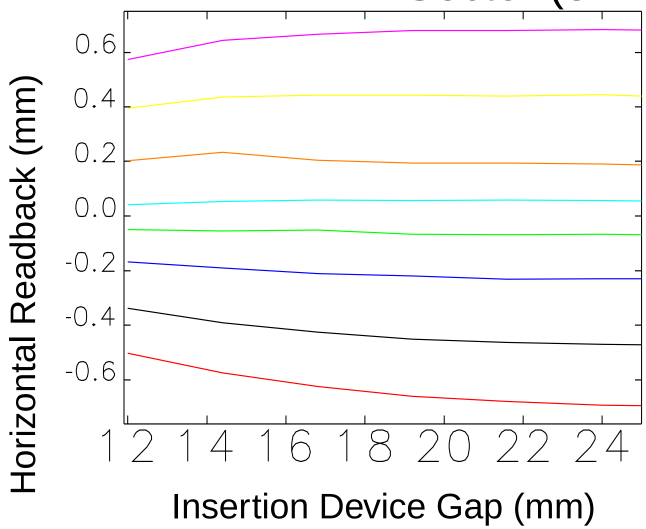

X-bpm housing
X-Y Translation Stage

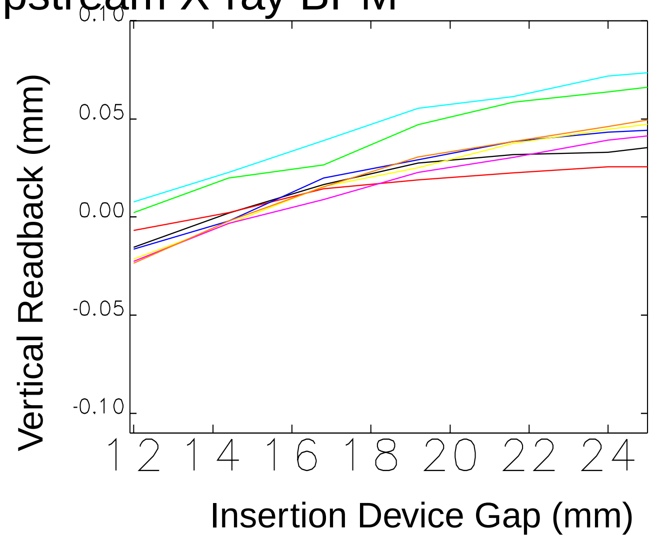
Noise Sources Impacting APS Orbit Stability

- **Magnet power supply noise / ripple**
  - **Dominant source of beam motion**
  - **DSP-based regulator prototyped**
- **RF system high voltage power supply**
  - **Induces 360 Hz phase (energy) ripple + harmonics**
- **Thermal effects (Tunnel air / water temperature)**
- **Earth tides**
- **Mechanical vibration**
  - **Affects primarily horizontal beam motion**
- **Insertion device gap changes <-----**

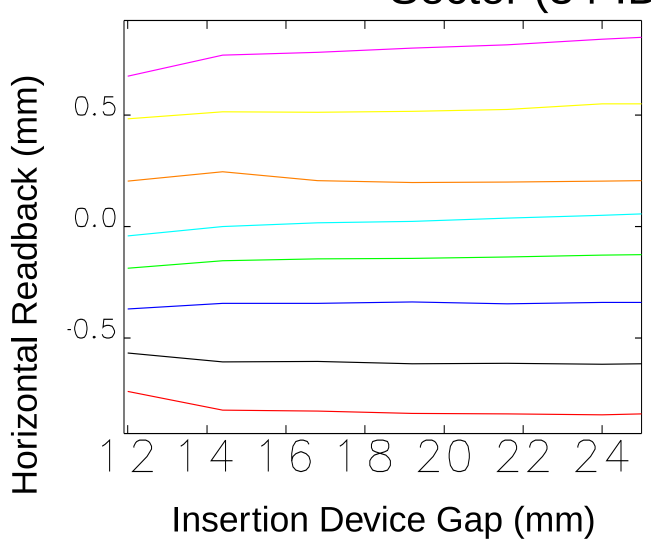
Variation of ID X-ray BPM Readbacks with Horizontal Position, Gap

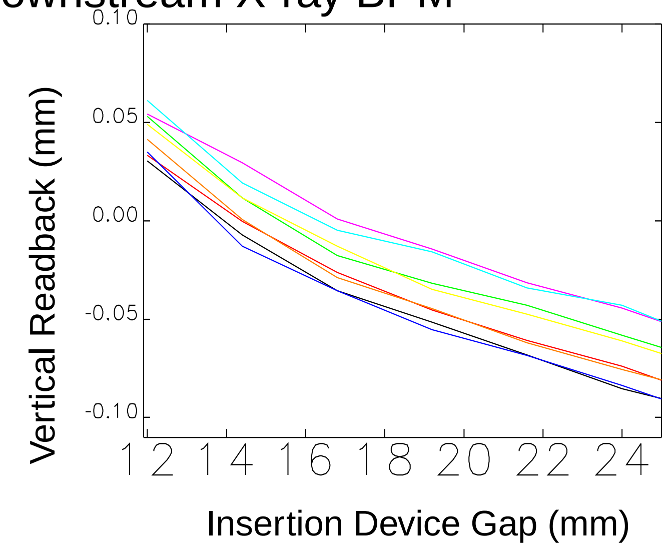
Sector (34-ID) Upstream X-ray BPM

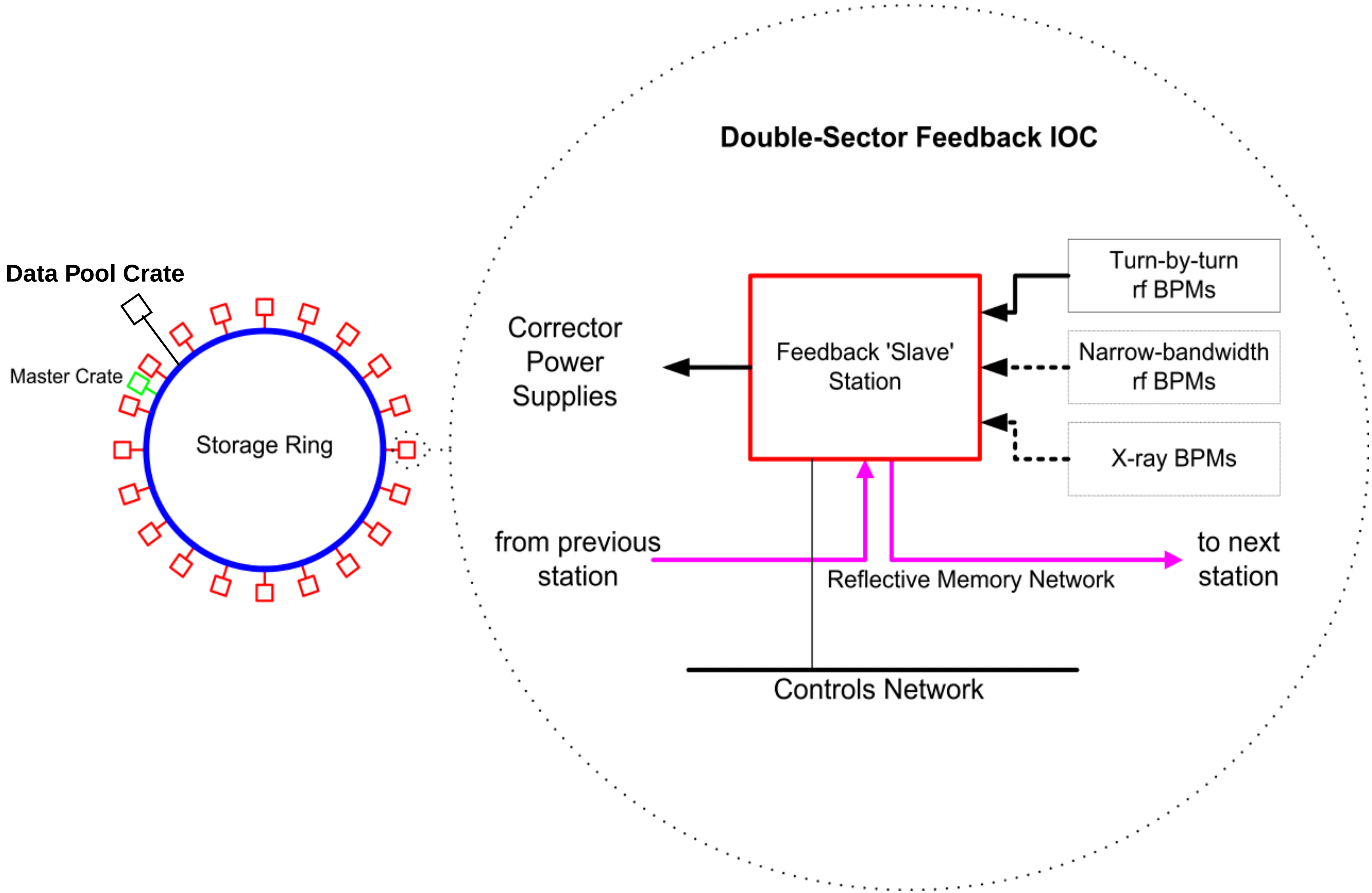


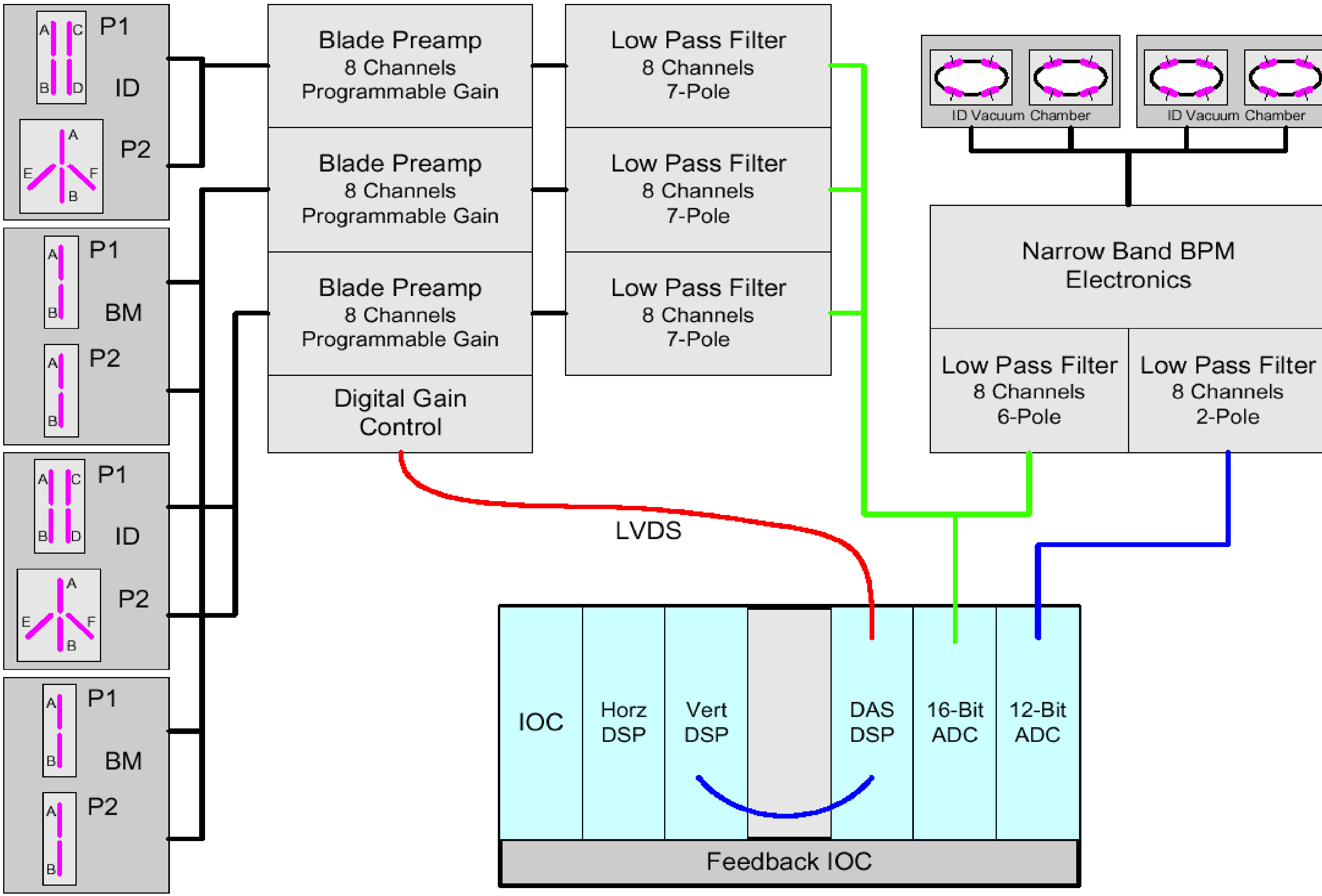


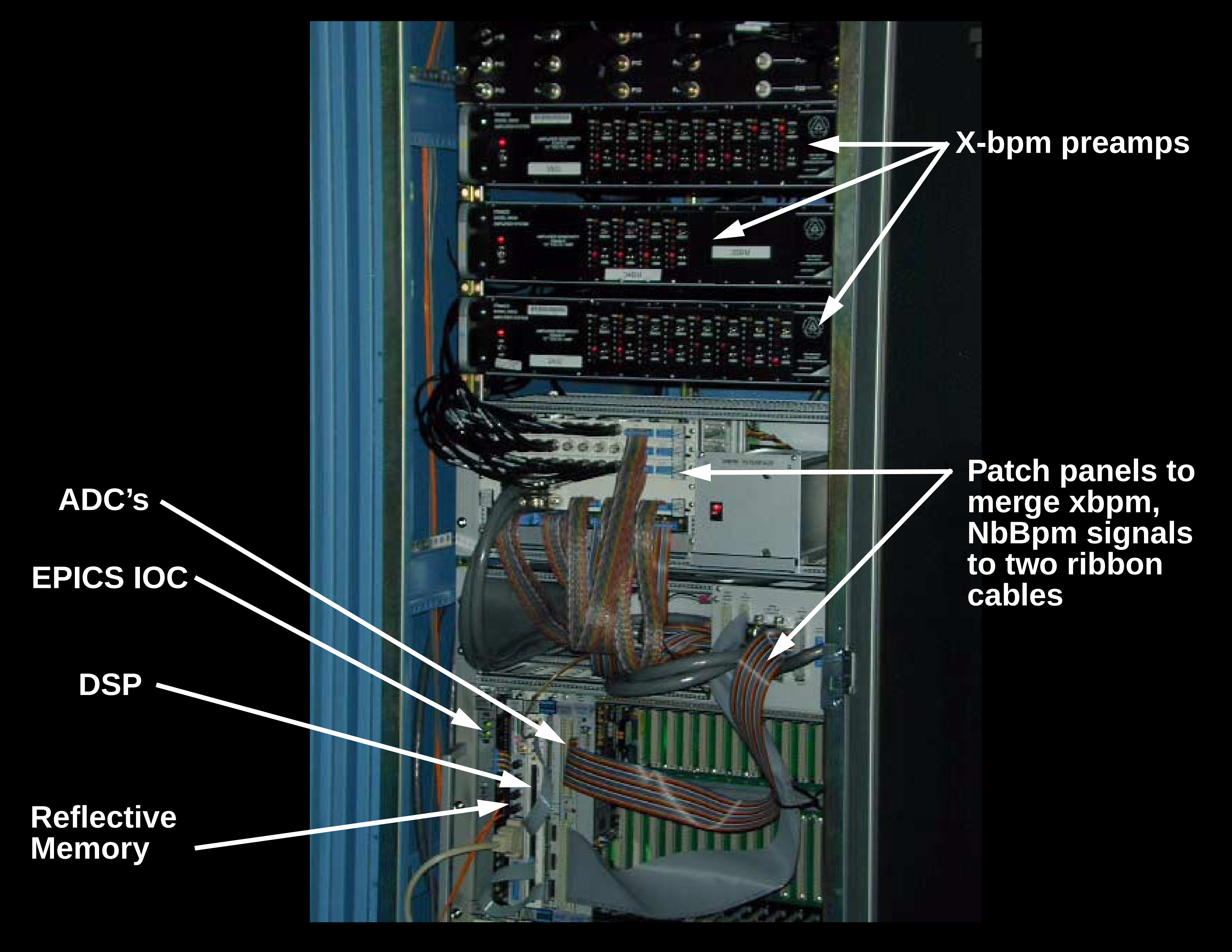
Sector (34-ID) Downstream X-ray BPM



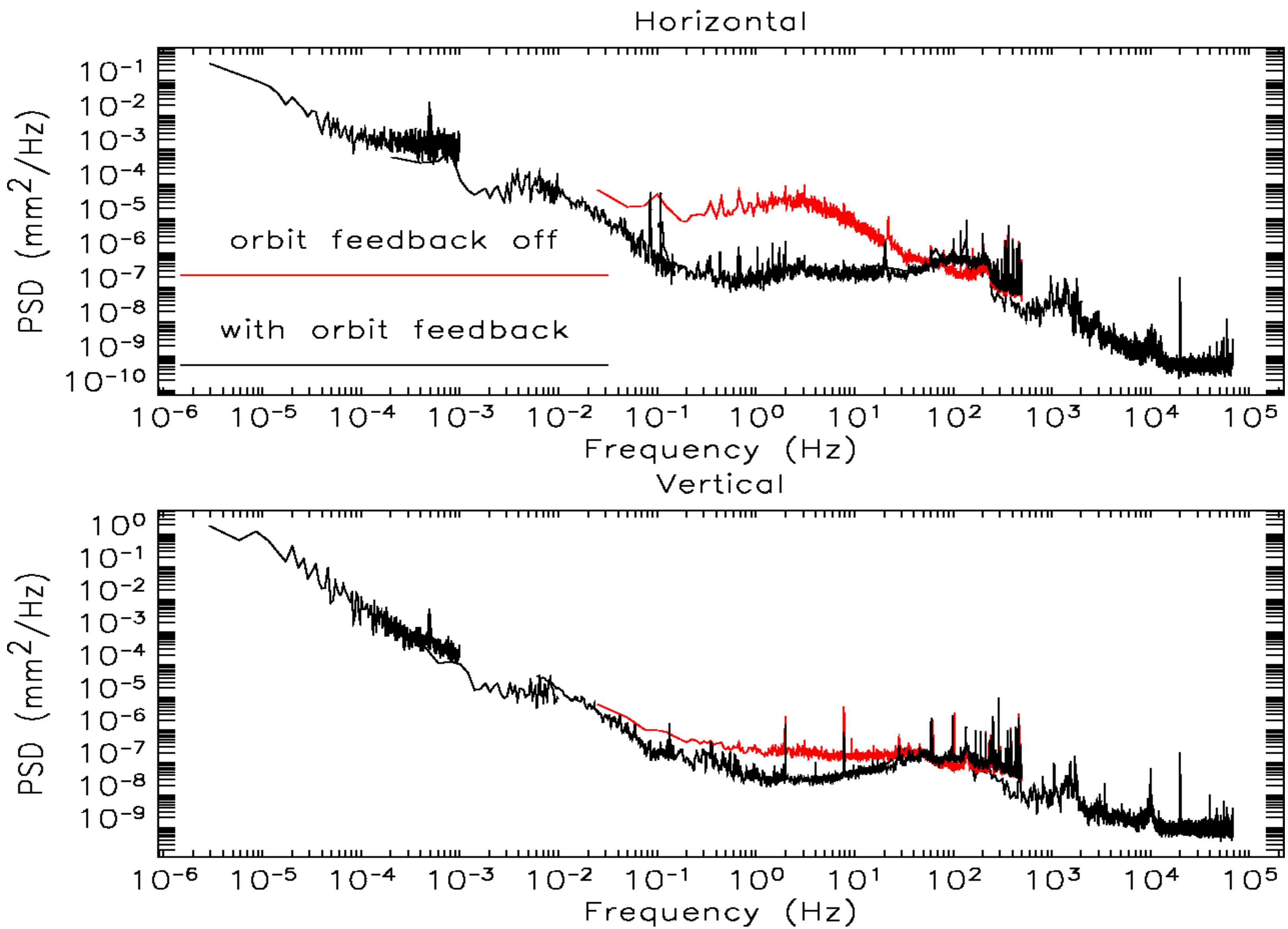


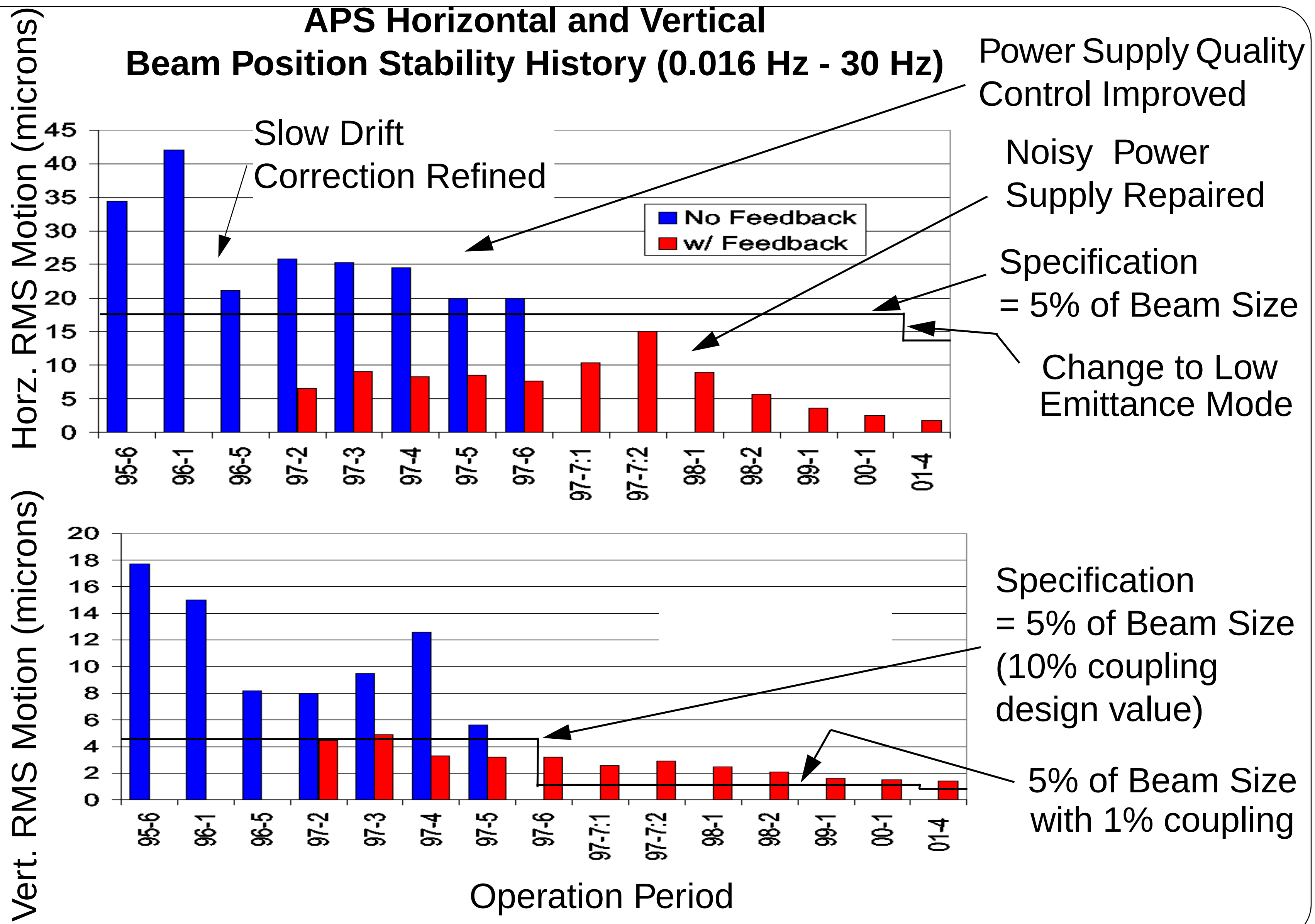

Data Pool Crate
Master Crate
Storage Ring
Double-Sector Feedback IOC
Corrector
Power
Supplies
Feedback 'Slave'
Station
Turn-by-turn
rf BPMs
Narrow-bandwidth
rf BPMs
X-ray BPMs
from previous
station
to next
station
Reflective Memory Network
Controls Network


P1
ID
P2
A
B
C
D
E
F
P1
BM
P2
P1
ID
P2
P1
BM
P2
Blade Preamp
8 Channels
Programmable Gain
Blade Preamp
8 Channels
Programmable Gain
Blade Preamp
8 Channels
Programmable Gain
Digital Gain Control
Low Pass Filter
8 Channels
7-Pole
Low Pass Filter
8 Channels
7-Pole
Low Pass Filter
8 Channels
7-Pole
ID Vacuum Chamber
ID Vacuum Chamber
Narrow Band BPM Electronics
Low Pass Filter
8 Channels
6-Pole
Low Pass Filter
8 Channels
2-Pole
LVDS
IOC
Horz DSP
Vert DSP
DAS DSP
16-Bit ADC
12-Bit ADC
Feedback IOC

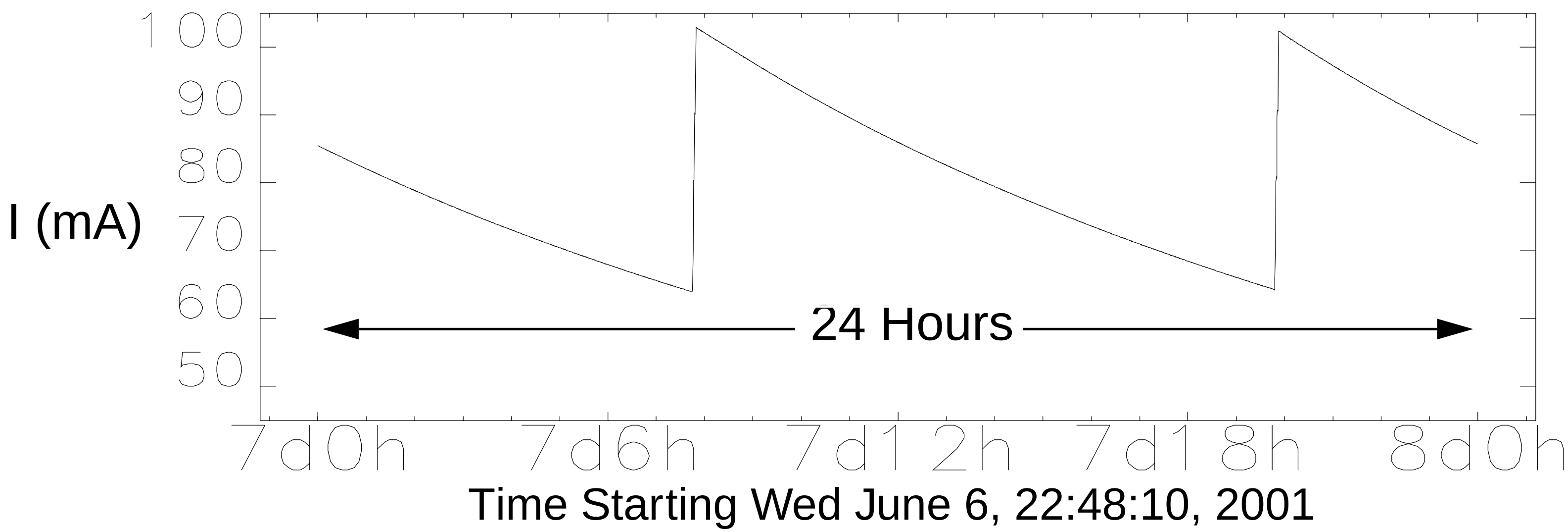

X-bpm preamps
Patch panels to merge xbpm, NbBpm signals to two ribbon cables
ADC's
EPICS IOC
DSP
Reflective Memory

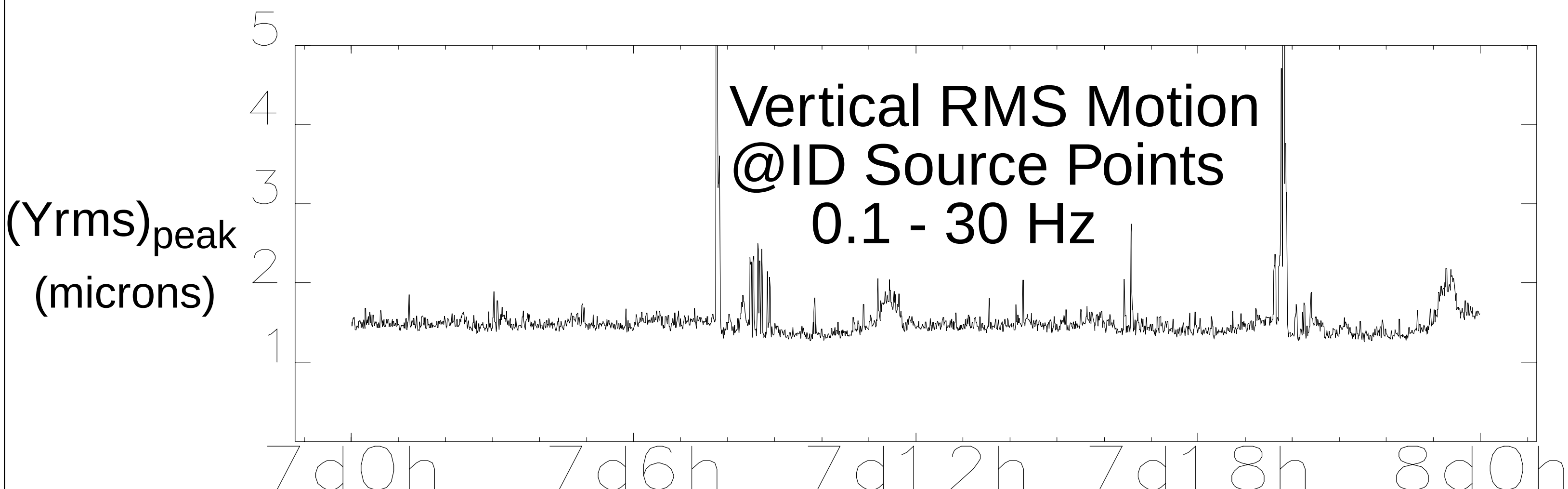
Spectrum of Beam Motion Averaged over ID Source Points



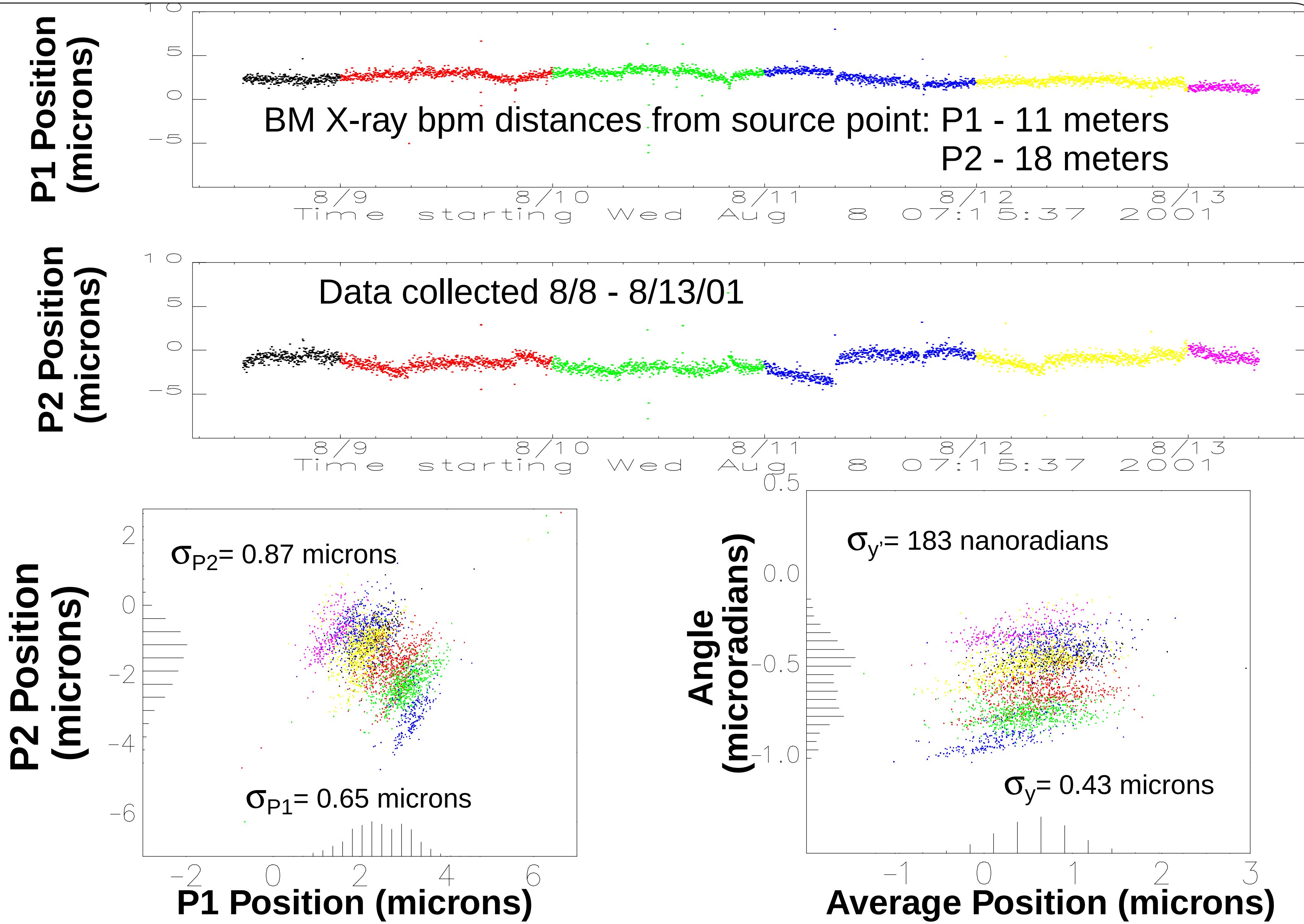

APS Horizontal and Vertical
Beam Position Stability History (0.016 Hz - 30 Hz)
Power Supply Quality
Control Improved
Slow Drift
Correction Refined
Noisy Power
Supply Repaired
Specification
= 5% of Beam Size
Change to Low
Emittance Mode
No Feedback
w/ Feedback
Horz. RMS Motion (microns)
45
40
35
30
25
20
15
10
5
0
95-6
96-1
96-5
97-2
97-3
97-4
97-5
97-6
97-7:1
97-7:2
98-1
98-2
99-1
00-1
01-4
Vert. RMS Motion (microns)
20
18
16
14
12
10
8
6
4
2
0
Specification
= 5% of Beam Size
(10% coupling
design value)
5% of Beam Size
with 1% coupling
95-6
96-1
96-5
97-2
97-3
97-4
97-5
97-6
97-7:1
97-7:2
98-1
98-2
99-1
00-1
01-4
Operation Period

Stored Beam Current





Plots showing < 200 nanoradian rms vertical beam stability over a 5 day period
Colors indicate data for individual days

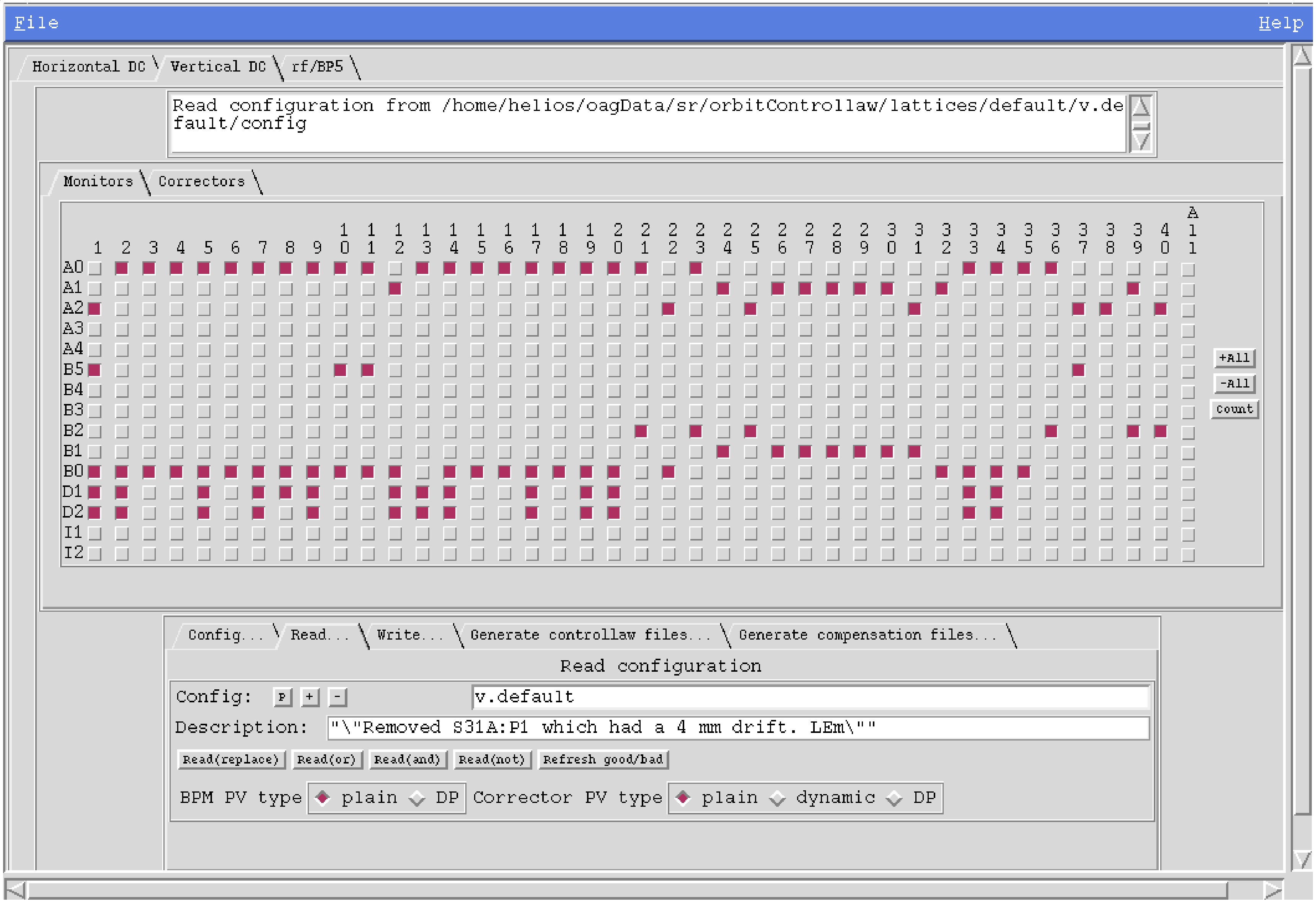


Recently Completed Upgrades

- Replaced X-ray bpm data acquisition (86 channels, BM and ID)
  - Allowed factor of ten reduction in long term vertical drift
- Fabricated mobile X-ray bpm translation stage controllers
  - Allows for convenient and precise calibration of x-bpms

Upgrade Strategy

- **Systems now in operation:**
  - **Real time feedback using monopulse RF bpms (0.1 - 30 hz closed loop bandwidth with 1.5 kHz data rate).**
  - **Software for reconfiguration of DC orbit control using arbitrary bpms, steering correctors, number of singular values, and bpm weights.**
  - **Software providing local steering on demand.**
  - **Vertical DC global orbit control using bending magnet x-bpms.**


File
Help
Horizontal DC
Vertical DC
rf/BPS
Read configuration from /home/helios/oagData/sr/orbitControllaw/lattices/default/v.default/config
Monitors
Correctors
A0
A1
A2
A3
A4
B5
B4
B3
B2
B1
B0
D1
D2
I1
I2
+All
-All
count
Config...
Read...
Write...
Generate controllaw files...
Generate compensation files...
Read configuration
Config:
v.default
Description:
"\"Removed S31A:P1 which had a 4 mm drift. LEm\""
Read(replace)
Read(or)
Read(and)
Read(not)
Refresh good/bad
BPM PV type
plain
DP
Corrector PV type
plain
dynamic
DP

- **Things we know how to do and will do in FY02:**
  - **Increase update rate of “DC” correction algorithm from 0.4 Hz to 50 Hz or more**
    - **Involves addition of “data pool” IOC hooked into reflective memory network**
  - **Implement feedforward to reduce ID gap change - induced orbit transients**
  - **Integrate insertion device x-bpms into global and local orbit control algorithms**
    - **Comprehensive understanding of systematic effects after two years’ intensive study are well in hand**

- **Long range upgrade plans:**

  - Incorporation of x-bpms and narrow-band bpms into fast feed-back algorithm (This places a fundamental limit on vertical beam size / brightness)

  - Blade geometry optimization of ID x-bpms

  - Design of x-bpm's for dual-undulator sources

Conclusions

- APS orbit correction system is mature, integrating RF and X-ray beam position monitors.
- System uses > 60 DSP's tied together with real-time reflective memory network.
- Bending magnet X-bpm's are in operation for DC orbit control.
- Data pool IOC will allow integration of insertion device X-bpm's into DC orbit control ('fast' feedforward necessary)
- Integration of X-bpm's into 1.5 kHz global feedback will allow sub-micron orbit stability from "DC" to 30 Hz.